# Lunar Program Industry Briefing
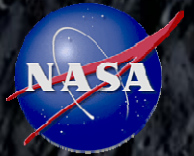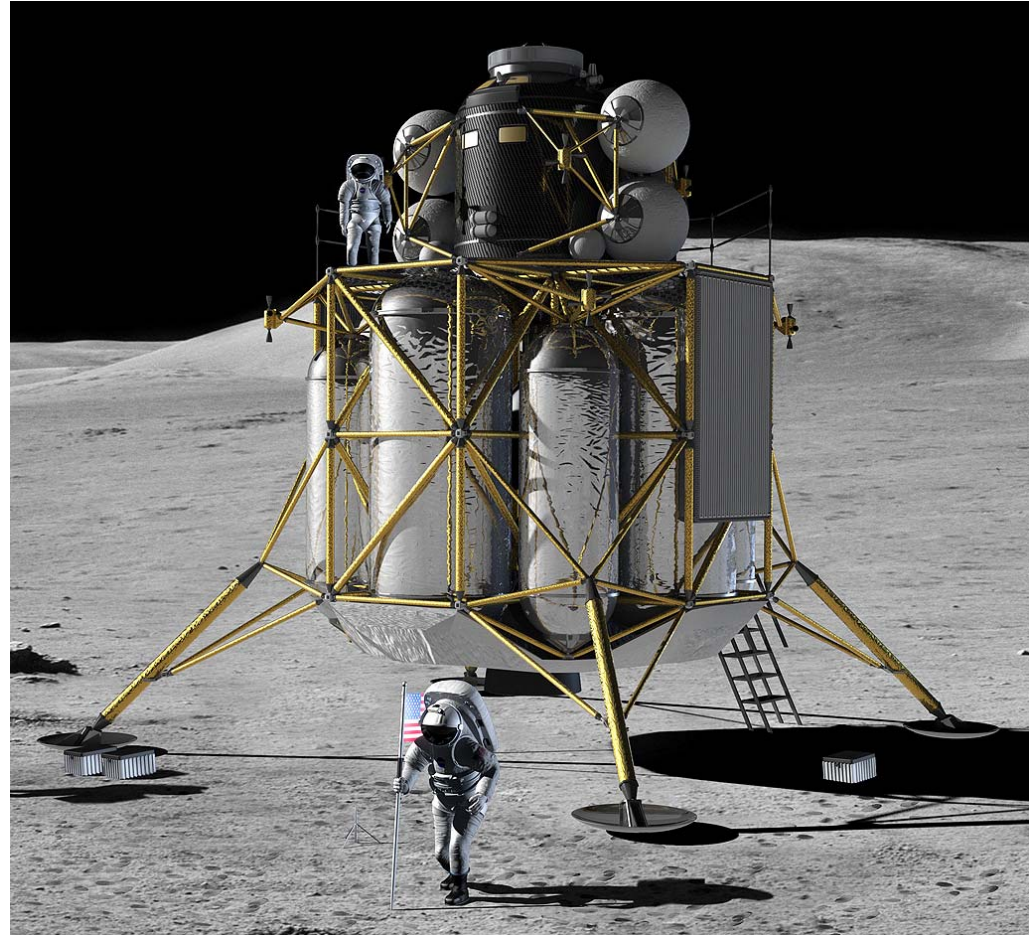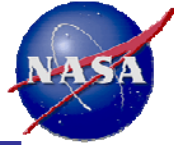## Altair Overview

**Clinton Dorris**
**Deputy Manager, Altair Project Office**

# Altair Lunar Lander

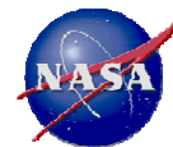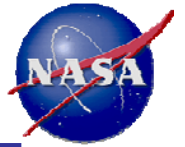- **4 crew to and from the surface**
  - Seven days on the surface
  - Lunar outpost crew rotation
- **Global access capability**
- **Anytime return to Earth**
- **Capability to land 14 to 17 metric tons of dedicated cargo**
- **Airlock for surface activities**
- **Descent stage:**
  - Liquid oxygen / liquid hydrogen propulsion
- **Ascent stage:**
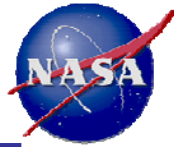  - Hypergolic propellants or liquid oxygen/methane

# Lander Concept Trades

Timeline headers:

| 2005 | 2006 | 2007 | 20 |
|---|---|---|---|

June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June

**ESAS Release**

**ESAS**

**LSAM Pre-Project**

**Lunar Lander Project**

**Altair Project**

**LAT-1**

**LAT-2**

**CxAT-Lunar**

**LLPS**

**LLPS RFI**

**LDAC-1**

**Parametric Modeling based on LDAC-1 bottoms-up design**

**LDAC-1Δ**
"Minimum Functional Vehicle"

**Parametric Modeling based on LDAC-1Δ bottoms-up design**

**LDAC-2**
"Minimum Flyable Vehicle"

**Parametri**

0507-ESAS-A
0507-ESAS-B
0507-ESAS-C
0507-ESAS-D
0507-ESAS-E
0507-ESAS-F
0507-ESAS-G
0507-ESAS-H
0507-ESAS-I
0507-ESAS-J

0507-ESAS-1

pre-ICPR: ~30 parametric variations in support of ICPR requirements decisions

0605-LLPS-1
0605-LLPS-2
0605-LLPS-3
0605-LLPS-4
0605-LLPS-5
0605-LLPS-6
0605-LLPS-7
0605-LLPS-8
0605-LLPS-9
0605-LLPS-10
0605-LLPS-11
0605-LLPS-12
0605-LLPS-13
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0605-LLPS-26
0605-LLPS-27
0605-LLPS-28
0605-LLPS-29
0605-LLPS-30

0606-LLPS-RFI-1
0606-LLPS-RFI-2
0606-LLPS-RFI-3
0606-LLPS-RFI-4
0606-LLPS-RFI-5
0606-LLPS-RFI-6

0609-LLPS-1
0609-LLPS-2
0609-LLPS-3
0609-LLPS-4
0609-LLPS-5
0609-LLPS-6
0609-LLPS-7

p0610-LAT-1
p0610-LAT-2
p0610-LAT-3
p0610-LAT-4

p0610-A

p0611-LAT-1
p0611-LAT-2

p611-A

p0611-A

p0612-A

p0701-A
p0701-B
p0701-C

p0702-A
p0702-C

p703-C-U
p703-C-C1
p703-D-C1
p703-E-U
p703-E-C1
p703-F-C1

706-A

p709-A

p707-A

p707-B

p710-A

p710-B

p711-C

p711-B

711-A

50 + parametric runs in support of CxAT-Lunar global access closure

p0804-A
p0804-B
p0805-C

p0801-A
p0801-B
p0801-C

p805-B

805-A

MIT concepts

# Detailed Approach for Design Team

♦ **Developing an in-house design utilizing a risk based approach**

♦ **Agency wide team**

♦ **Design emphasis on the integrated vehicle versus elements**

♦ **Focused on Design ('D' in DAC)**
  - Developed detailed Master Equipment List (over 6000 components)
  - Developed detailed Powered Equipment List
  - Produced sub-system schematics
  - NASTRAN analysis using Finite Element Models
  - Performed high-level consumables and resource utilization analysis
  - Sub-system performance analysis by sub-system leads

♦ **Keep process overhead to the minimum required**
  - Recognizing that a small, dynamic team doesn't need all of the process overhead that a much larger one does
  - But…. It still needs the basics

# Minimum Functionality/Risk-Informed Design Approach

♦ **Altair took a true risk informed design approach, starting with a minimum functionality design and adding from there to reduce risk.**

♦ **"Minimum Functionality" is a design philosophy that begins with a vehicle that will perform the mission, and no more than that**

- Does not consider contingencies
- Does not have added redundancy ("single string" approach)
- Provides early, critical insight into the overall viability of the end-to-end architecture
- Provides a starting point to make informed cost/risk trades and consciously buy down risk
- A "Minimum Functionality" vehicle is NOT a design that would ever be contemplated as a "flyable" design!
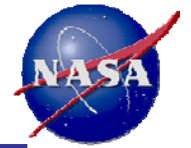
# Lunar Lander Summary Schedule



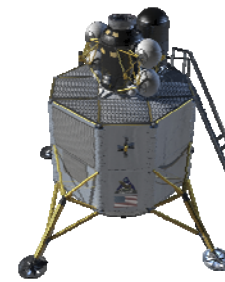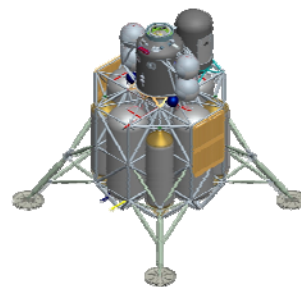Timeline header: Jun 07 | Sept 07 | Dec 07 | Mar 08 | Jun 08 | Sept 08 | Dec 08 | Mar 09 | Jun 09 | Sept 09

▼ CxP LCCR

**In-House Design Effort**

- **LDAC-1** — **Minimum Functional Vehicle**
- **LDAC-2** — **Safety Enhanced Vehicle**
  **Safety / Reliability Upgrades (LOC)**
  **10 meter shroud upgrade**
- **LDAC-3** — **Upgraded Flyable Vehicle**
  **Additional safety, reliability and functionality (LOM)**
  **Global Access upgrade**
- **RAC-1** — **Requirements Focus**
  **Close the gap with the CARD**
  **Draft SRD, IRDs**
- **LDAC-4**

**Industry Participation**

- ▲ **Industry Day – 12/13/07**
- **BAA Study Contracts**
- ▲ **Cx Lunar Update – 9/25/08**

# Lander Design Analysis Cycles

- ◆ **LDAC-1: Minimum Functional Vehicle**
  - • Habitation module/airlock embedded "mid-bay" within descent module structure
  - • Designed for 8.4 meter Ares V shroud (7.5 meter diameter dynamic envelope)
- ◆ **LDAC-1Δ: Minimum Functional Vehicle with optimized descent module structure**
  - • Ascent module and airlock on top deck of "flatbed" lander
- ◆ **LDAC-2: Safety/Reliability Upgraded Vehicle**
  - • Loss of Crew (LOC) risks addressed
  - • Designed for 10 meter Ares V shroud (8.8 meter diameter dynamic envelope)



| "Minimum Functional" design 8.4 m Ares V shroud, 45 mt control mass | | "Safety Enhanced" design 10 m Ares V shroud | "Reliability Enhanced" design |
| --- | --- | --- | --- |
| **Altair Design Cycle:** LDAC-1 | LDAC-1Δ | LDAC-2 | LDAC-3 |

- ◆ **LDAC-3: Upgraded Flyable Vehicle (currently in progress)**
  - • Loss of Mission (LOM) risks addressed
  - • Global Access Capability
- ◆ **Future LDACs: Additional Functionality; close gap with CARD requirements**

# Lunar Lander Design: Tradeoffs Among Many Competing Factors
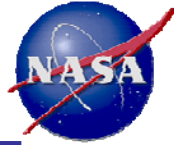
- **Delta-V – large velocity changes for lunar descent, ascent**
  - Large LOI velocity change with CEV attached
- **Propellant tank size**
  - Large H2 tanks – packaging challenge
- **Launch shroud diameter and length**
  - "building a ship in a bottle"
- **Launch and TLI loads – control buckling, bending and stack frequencies**
- **c.g. control – packaging propellant, stages and payloads to keep c.g. on/near centerline for vehicle control**
- **Ascent – duration, life support, power, returned payload**
- **Fire in the hole**
- **Abort capabilities throughout all mission phases**
- **Crew access (both among modules and to surface)**
- **Cargo unloading and access**
- **Crew visibility – for landing, docking**

# Lunar Orbit Insertion (LOI) Trade
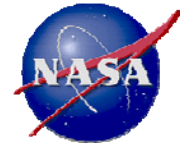
◆ **Changing the LOI function on Altair requires a dedicated 3rd stage**

- Small performance gains realized (additional mass performance) for options with more efficient staging fractions
- Additional risk, DDT&E costs and parasitic mass outweigh the performance gains

**Summary of Selected Options**

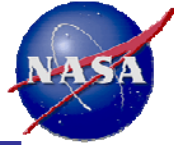| | Reference | LV / LL Pair 2 | LCCR* | LV / LL Pair 6 | LV / LL Pair 7 | LV / LL Pair 8 |
|---|---|---|---|---|---|---|
| | P711-B LOX LH2 DM DM( LOI / Desc.) | P711-B LOX LH2 DM DM( LOI / Desc.) | P711-B LOX LH2 DM DM( LOI / Desc) | Non-LOI LOX LH2 DM DM(Desc.) | Non-LOI LOX LH2 DM DM( LOI / Desc.) | Non-LOI LOX LH2 DM DM( LOI / Desc.) |
| | 51.0.39 2 Liq Stage (2) 5 Seg SRB 5 Eng RS-68 EDS (Asc./ TLI) | 51.0.62 2 Liq Stage (2) 5.5 Seg SRB 5 Eng RS-68 EDS (Asc./ TLI) | 51.0.47 2 Liq Stage (2) 5.5 Seg SRB 6 Eng RS-68 EDS (Asc./ TLI) 1 J2X | LOI Stage 51.0.62 2 Liq Stage (2) 5.5 Seg SRB 5 Eng RS-68 EDS (Asc./ TLI) 1 J2X | 47.03.16 3 Liq Stage (2) 5 Seg SRB 6 Eng RS-68 5" Eng J2 D4 EDS (Asc./ TLI / LOI) 6" RL-10 A4 *Eng Out | 47.03.15 3 Liq Stage (2) 5 Seg SRB 6 Eng RS-68 5" Eng J2 D4 EDS (Asc./ TLI/ LOI) 6" RL-10 B2 *Eng Out |
| Altair+PL+MR+PLA (t) Altair w/ MR + PLA **Sortie Mission** | 42.1+0.5+3.0+0.7 **46.3 mt** | 42.1+0.5+3.0+0.7 **46.3 mt** | 42.1+0.5+3.0+0.7 **46.3 mt** | 25.3+0.5+2.5+0.4 **28.7 mt** | 25.3+0.5+2.5+0.4 **28.7 mt** | 25.3+0.5+2.5+0.4 **28.7 mt** |
| Ares V Perf (mt) **TLI / LOI** | **63.6** / n/a | **72.2** / n/a | **74.7** / n/a | **72.2** / 48.7 | ~70.5* / 54.5 | ~73.1* / 58.4 |
| +/- Cum Margin (mt) (Ares -Orion -Altair Net - PLA) **[TLI]** | **[+0.1]:[+0.1]** | **[+ 8.7]:[+3.0]** | **[+11.2]:[+3.0]** | **[+8.6]:[+2.5]** (0.7 mf) | [+7.6]:[+7.6] | [+11.5]:[+11.5] |
| Ares V Cost ($M) **DDTE / 1 Flt Unit** | **$6872 / $827** | **$8107 / $1088** | **$8165 / $1132** | **$8861 / $1194** | $9142 / $1275 | $9142 / $1275 |
| Altair Cost ($M) **DDTE / 1 Flt Unit** | **$4126 / $595** | **$4126 / $595** | **$4126 / $595** | **$4022 / $580** | $4022 / $580 | $4022 / $580 |
| PLOM **[Ares V]: [Altair] Total** | [1/66(TLI)]:[1/75] 1/35 | [1/62(TLI)]:[1/75] 1/34 | [TBD]: [1/75] | [1/62(TLI)]:[1/91]; [TBD LOI stage] 1/34 | [1/64(LOI)]:[1/91] 1/38 | [1/64(LOI)]:[1/91] 1/38 |

*Approximate Equivalent TLI Perf.

◆ **Moving LOI function to Ares V requires a 3 stage vehicle**

- additional $1.0B DDTE cost
- less than half a metric ton gain at TLI above the current Ares V LCCR configuration

**LOI function retained on lander descent stage**
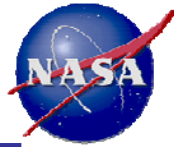
# Altair Vehicle Architecture

**Airlock**

**Ascent Module**
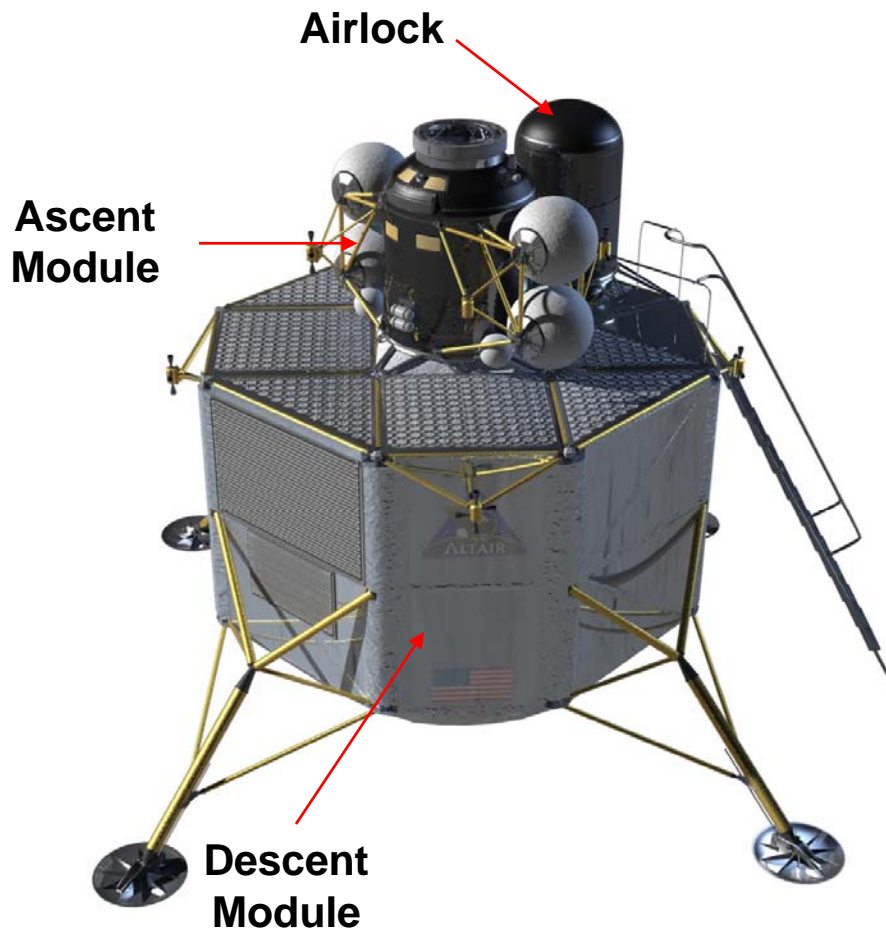
**Descent Module**

- ♦ **Three Primary Elements**
  - • Descent Module
    - – Provides propulsion for TCMs, LOI, and powered descent
    - – Provides power during lunar orbit, descent, and surface operations
    - – Serves as platform for lunar landing and liftoff of ascent module
    - – Designed to fit within 10 meter shroud
    - – **Liquid oxygen / liquid hydrogen propulsion**
    - – **Fuel cell powered**
  - • Ascent Module
    - – Provides habitable volume for four during descent, surface, and ascent operations
    - – Contains cockpit and majority of avionics
    - – **Provides propulsion for ascent from lunar surface after surface mission (hyper or LOX/Meth)**
    - – **Battery Powered**
  - • Airlock
    - – Accommodates two crew per ingress / egress
    - – Connected to ascent module via short tunnel
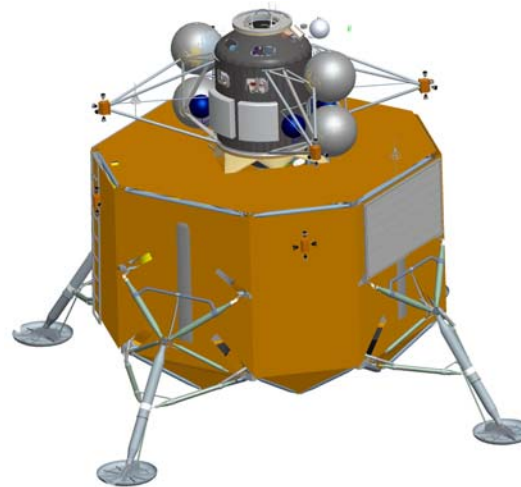    - – Remains with descent module on lunar surface after ascent module liftoff
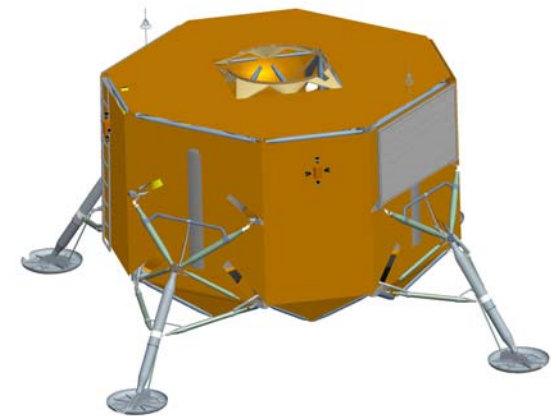
# Altair Configuration Variants
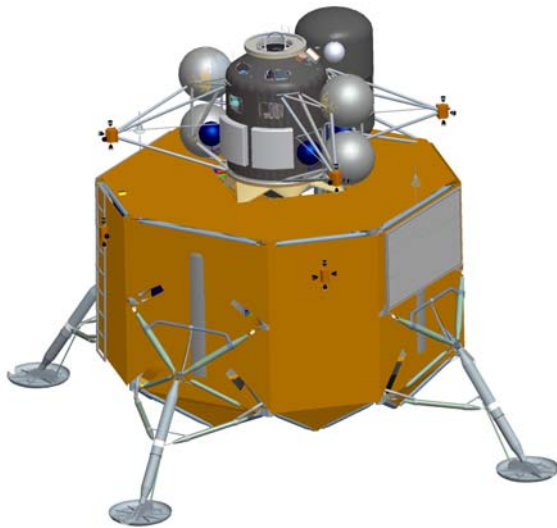


**Sortie Variant**

Descent Module
Ascent Module
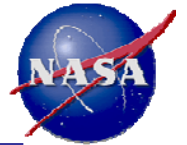Airlock

**Outpost Variant**

Descent Module
Ascent Module

**Cargo Variant**

Descent Module
Cargo on Upper Deck

# Altair Technology Prioritization Results

| Rank | Technology Need |
|------|-----------------|
| 1 | **Highly Reliable LOX/LH2 Throttling Engine** |
| 2 | **Cryogenic Fluid Management** |
| 3 | **LO2/LCH4 Main Engine & RCS** |
| 4 | **Composite Primary Structure Technology** |
| 5 | **Hazard Detection and Avoidance** |
| 6 | **Radiation Effects Mitigation and Environmental Hardness** |
| 7 | **CO2 and Moisture Removal System** |
| 8 | **Low Cycle-Life Rechargeable Battery** |
| 9 | **Low Mass, High Reliability PEM Fuel Cell** |
| 10 | **High Pressure Oxygen** |
| 11 | ***Lander Dust Mitigation*** |
| 12 | ***Sublimator- driven Coldplate*** |
| 13 | ***Crew Composite Pressure Vessel Design and Validation*** |

**Blue = Critical Technology    Italics = Highly Desirable Technology**

# Altair Summary
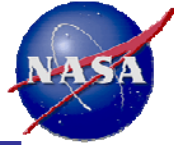
♦ **Current Altair design demonstrates a lander design that closes within the Constellation transportation architecture**

♦ **The Project has taken methodical, risk informed design approach**

♦ **Altair has developed a detailed bottoms-up cost estimate**

♦ **A design concept exists**

- Current Master Equipment List includes over 6000 items
- CAD models
- FEM and Nastran analysis
- Integrated schematics and individual system schematics, etc.

♦ **The current design concept is not necessarily "the" design**

- Too early to downselect to point design
- However, a critical part of the process to:
  - Understand design drivers well enough to write good requirements for SRR
  - Ensures integration with overall Cx architecture
  - Ensures a viable mission concept exists